Systematic SN Ia Spectral Studies from the SDSS-II Supernova Survey

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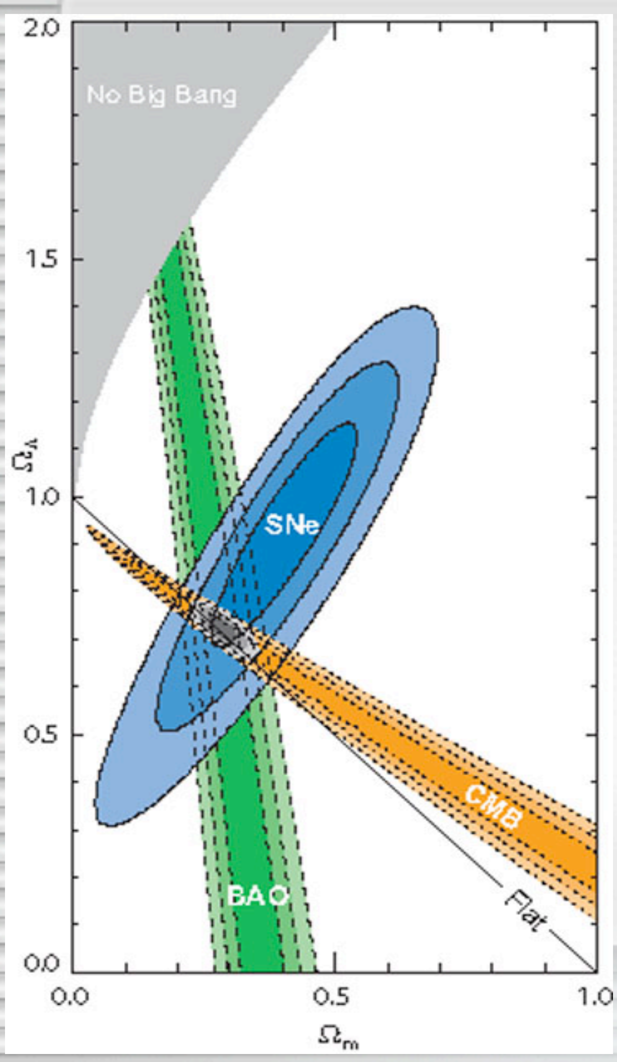
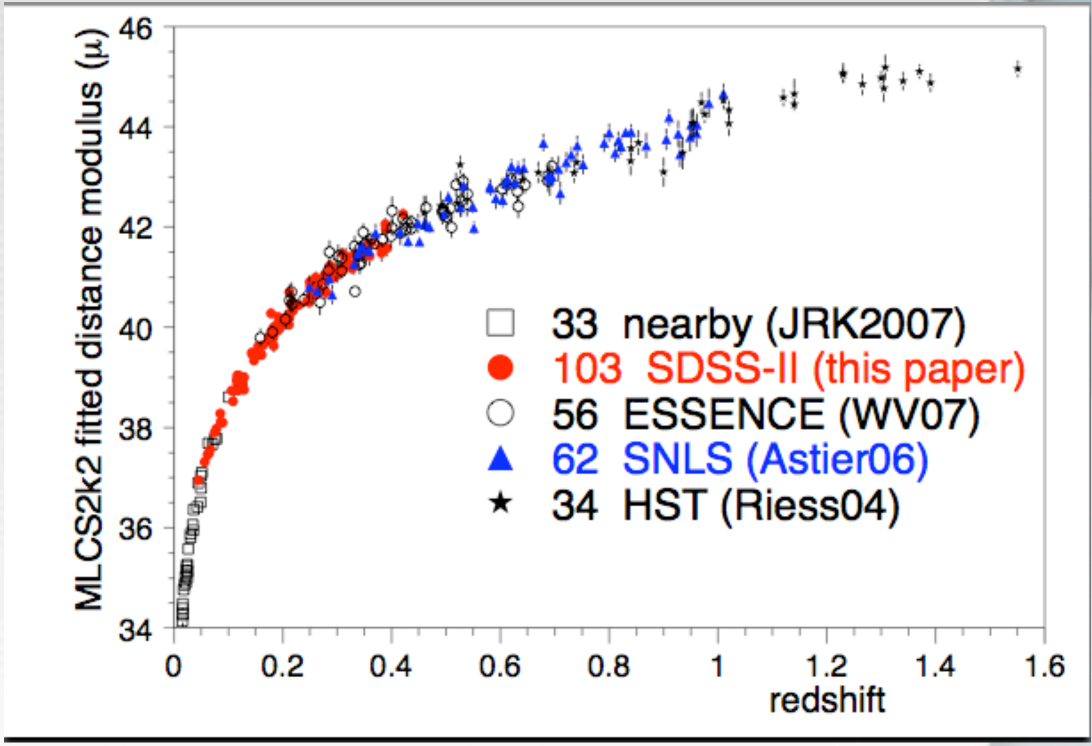
Outline

- Goal - SN Cosmology
- Data Calibration
- Spectral Measurement
- Preliminary Results

SNe Ia are used as empirical distance indicators for cosmology after light curve calibration.





Left: Kowalski et al. 2008; Up: Kessler et al. 2009(in prep)

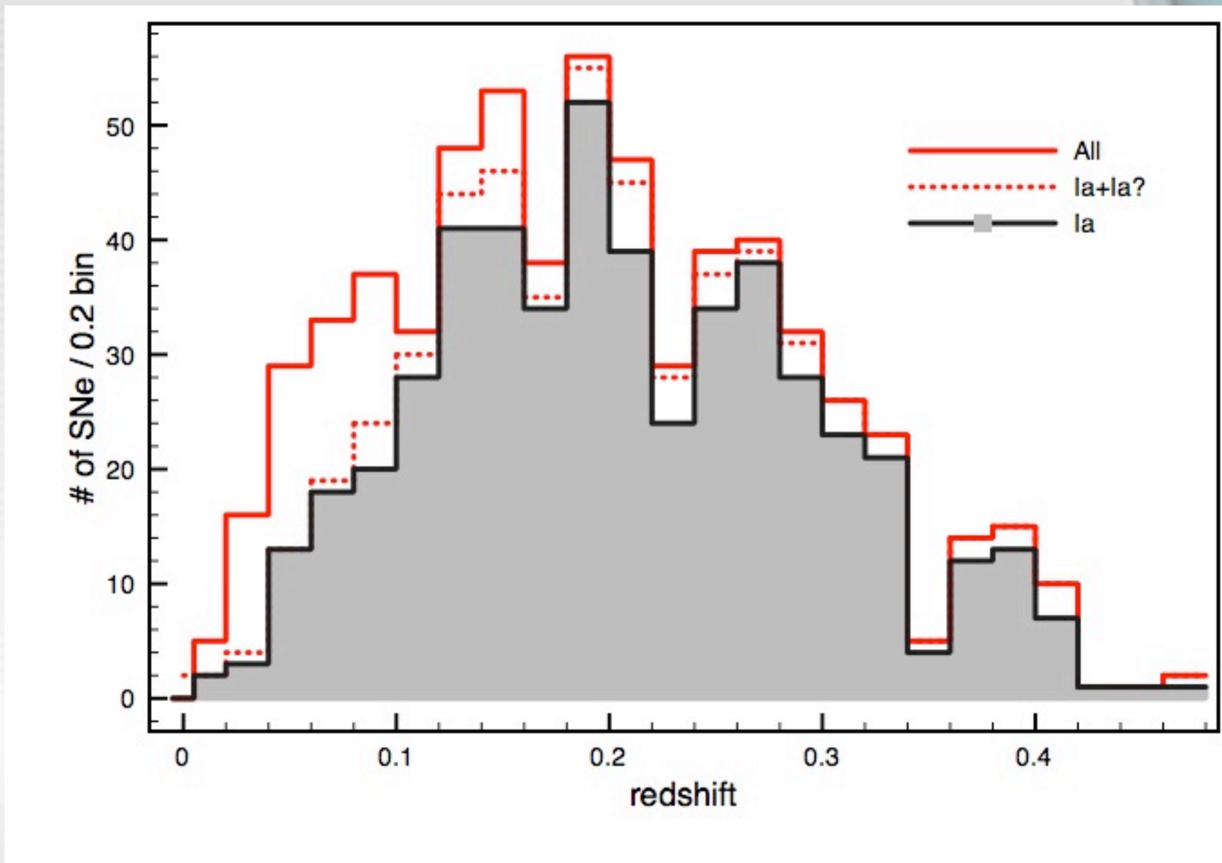
Systematic uncertainties are critical, and thus we need to understand SNe Ia better.

- Any **evolution** effect over cosmological time-scale?
- How **diverse** are SNe Ia?
  - Increase the confidence in using them for cosmology;
  - Identifying the nature of the progenitor system.
- Independent **luminosity indicators** with distinct systematic errors?

Spectroscopy could help!

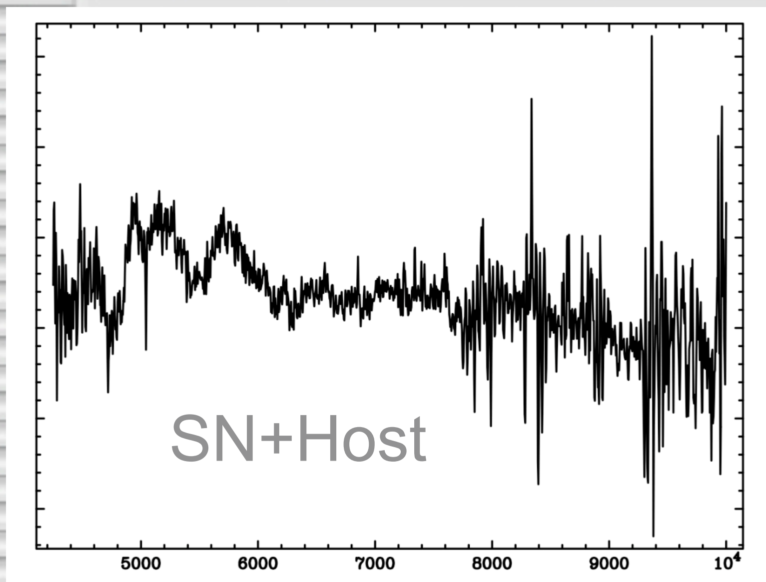
Data Set: 3 Year SDSS-II SN Survey Spectra

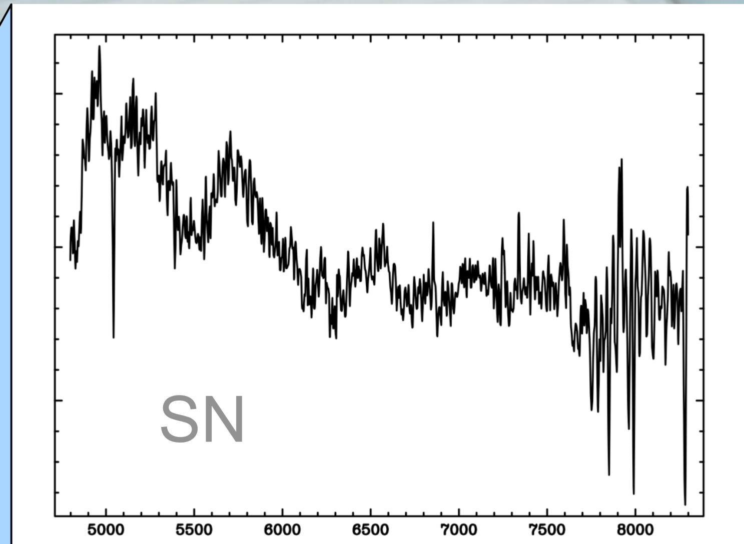
- ~**500** Confirmed Ia with ~**760** spectra from 14 telescopes;
- S/N: ~2 (HET etc.) to ~20; (Subaru, Keck etc.);
- ~-10d to ~40d.



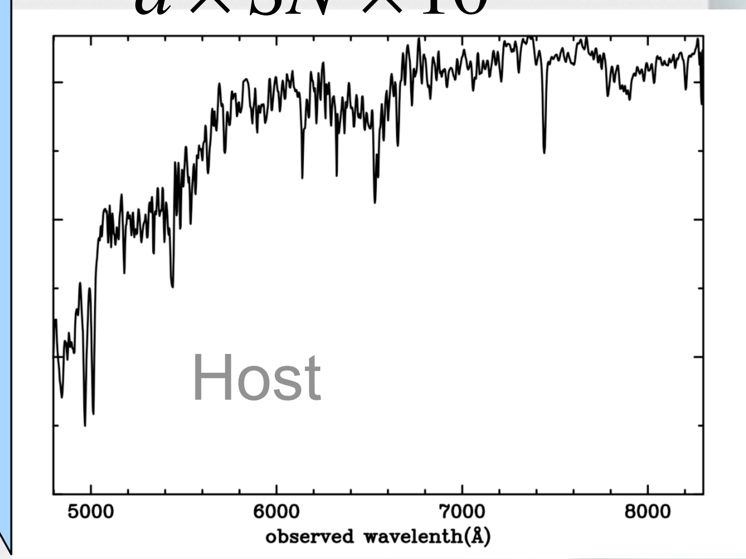
90% spectra have substantial **host contamination** (20% - 90%). Proper host subtraction is essential.

- **a, bi** - fit parameters;
- **SN** - SN Templates (Hsiao et al. 2007);
- **Eigencomp** - SDSS Galaxy Eigenmodes





$$a \times SN \times 10^{-0.4 A_\lambda}$$

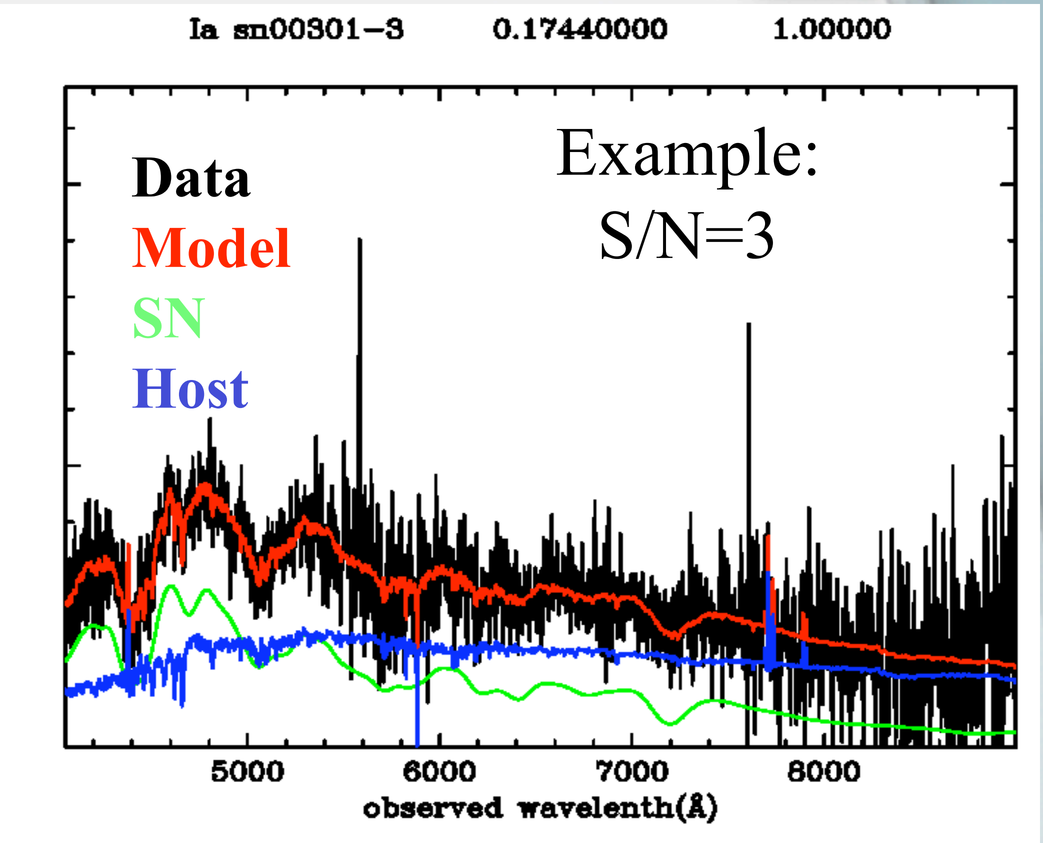


$$\sum b_i \times Eigencomp_i$$

- Cardelli reddening law (Cardelli 1998);
- Adopt Av from light curve;
- Adopt z and type from the cross-correlation analysis;
- Adopt host colors from SDSS photometry.

Host Subtraction Tests with Simulated Spectra

- SN Spectra from Hsiao Templates (-8 to 20d);
- Galaxy Spectra constructed from SDSS eigenspectra;
- Construct the spectra under the same model;
- Adopt variance spectra from real observations and then simulate noise accordingly to produce various S/N;



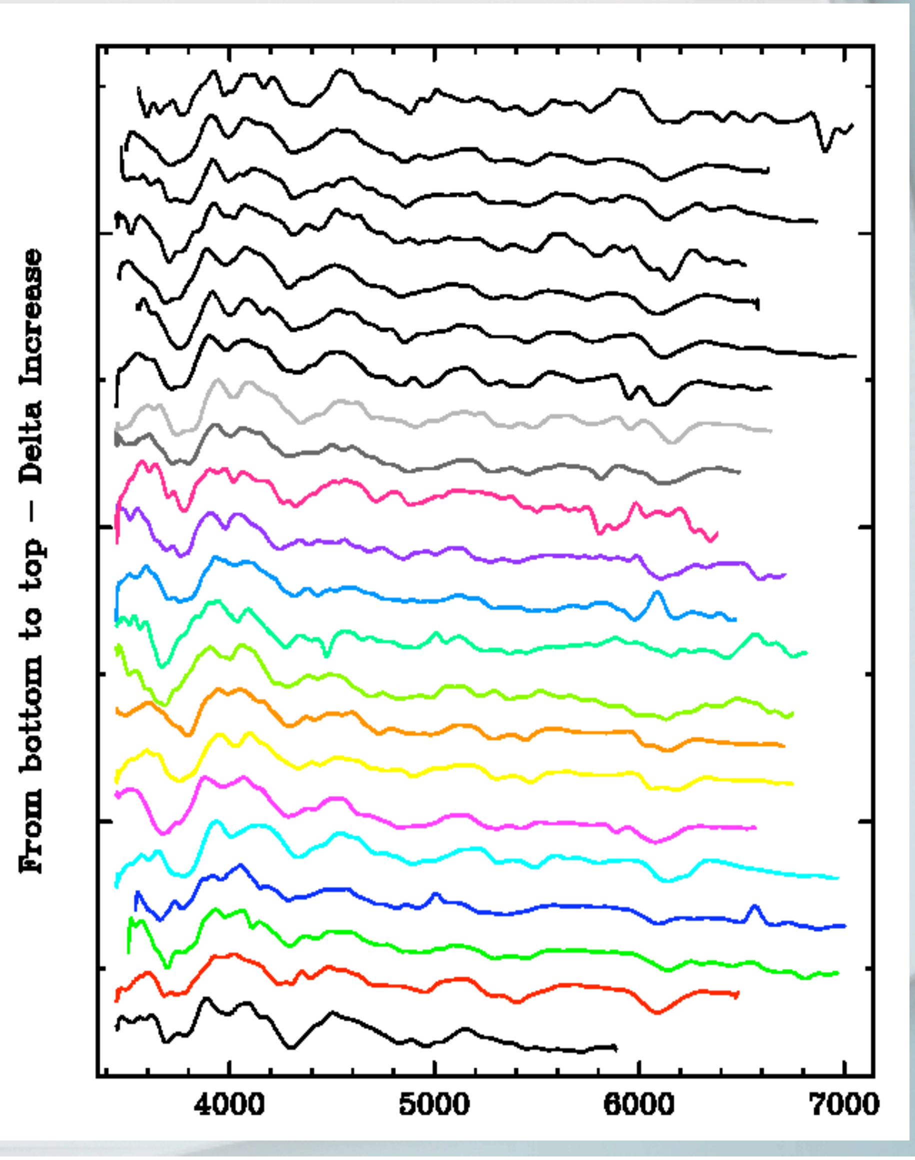
Test Resulst:

- Extracted SN spectrum agrees quite well with the original SN component.
- σ (SN Fraction) is within **6%** for the simulated spectra with **S/N >=3**.

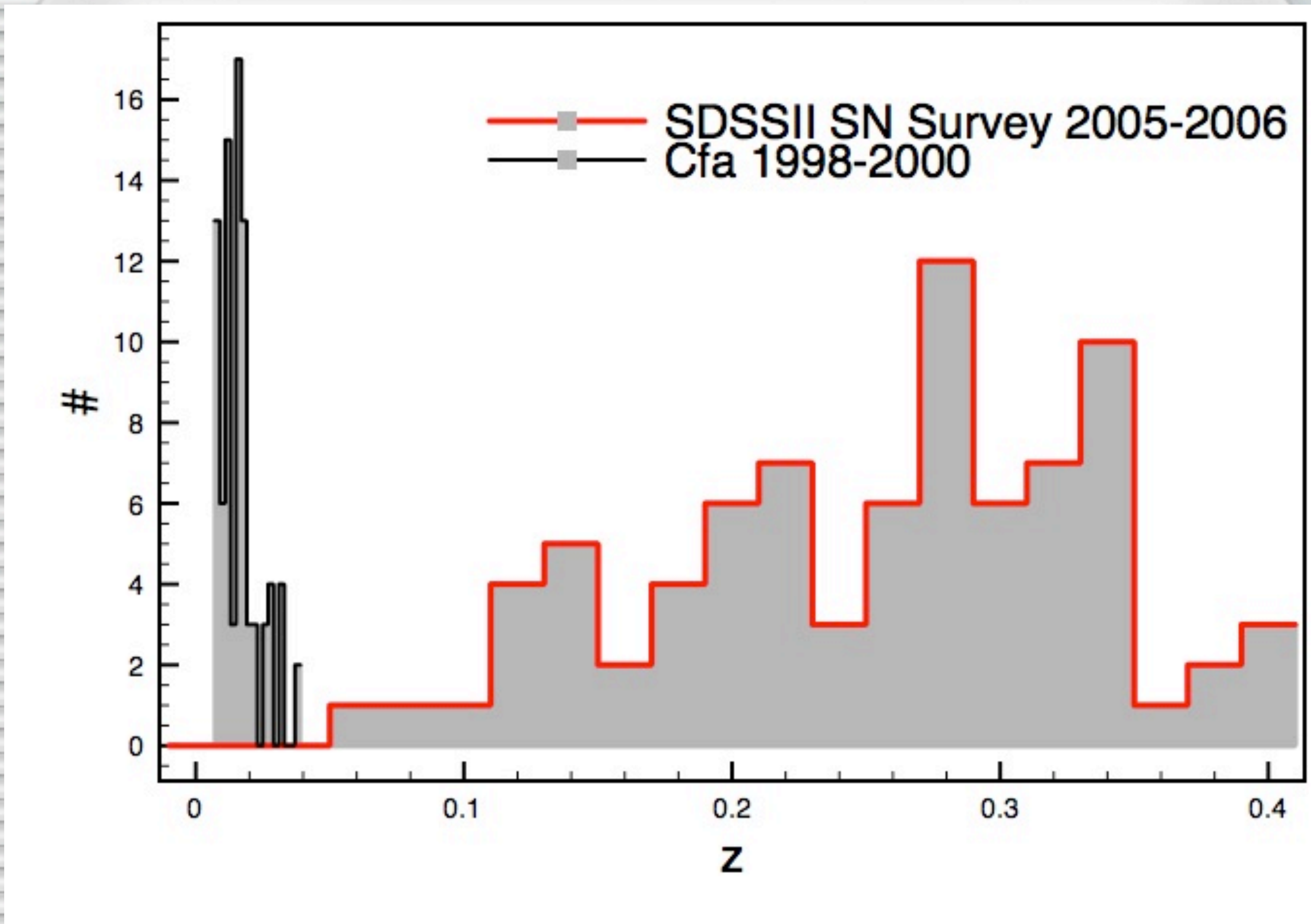
Selected SDSS-II SN Survey Sample for Systematic Spectral Studies

- 2005/2006 Host-subtracted Spectra with SN Light > 30%; (exclude NTT/NOT)
- S/N > 2;
- within +- 7d;
- S/N(gri) > 5;
- Smoothed with inverse-variance weighted Gaussian filter.

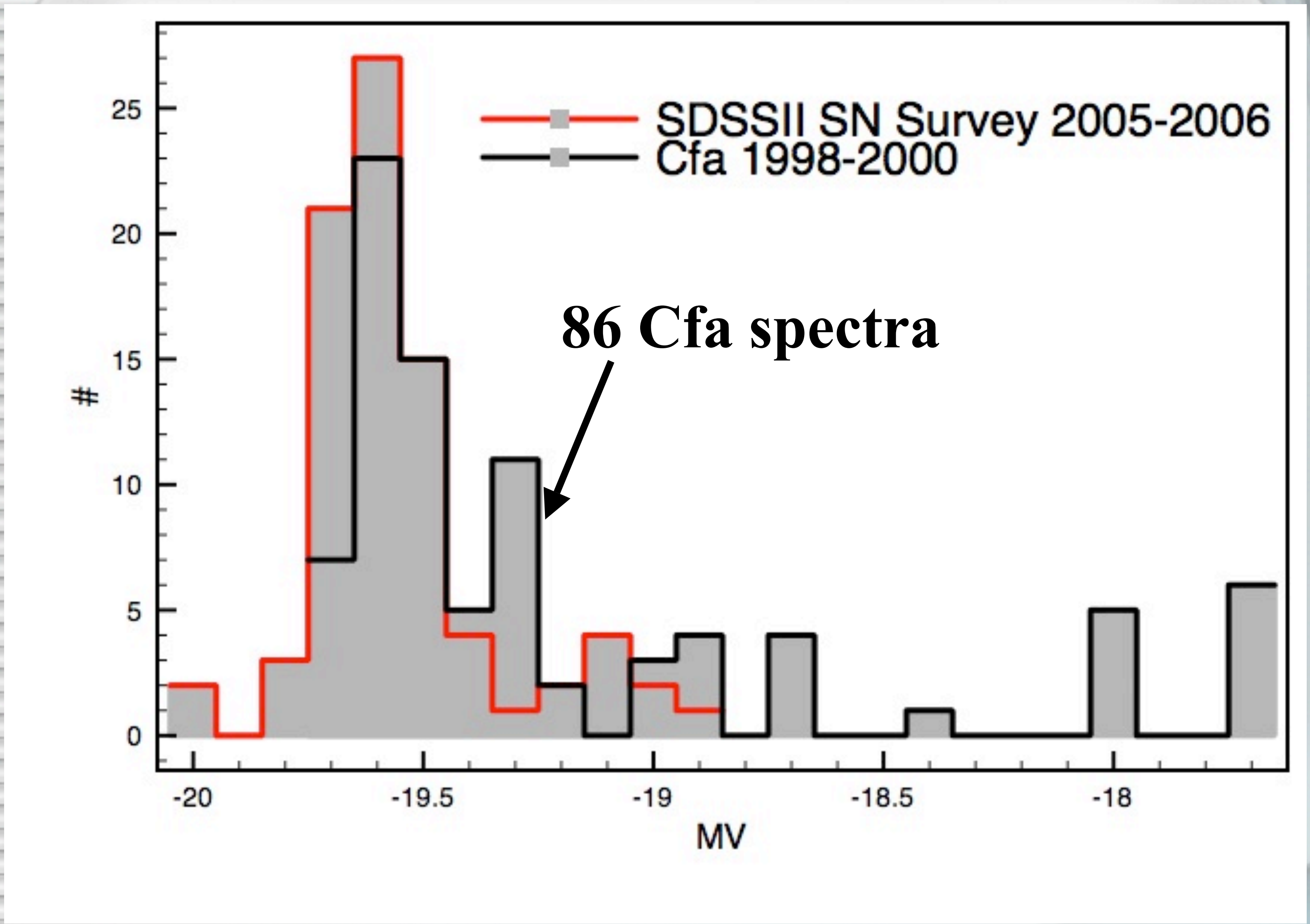
➔78 spectra



Include 1998-2000 Cfa published spectra…

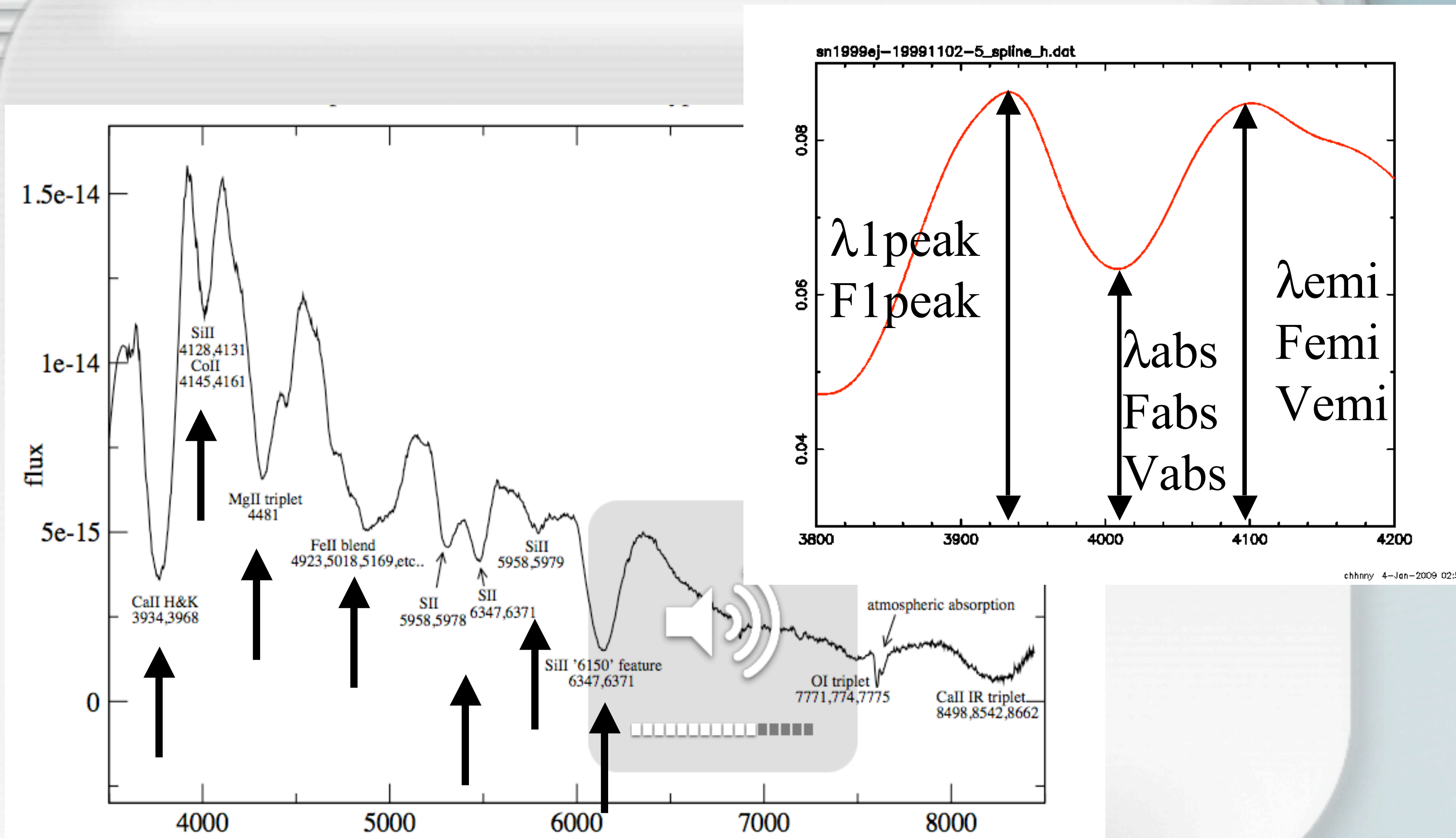


… and apply the same cut and analysis.



Spectral Measurement and Correlation Study

1) Measure [λ, F, V, Pseudo-EW, LineStr, FWHM] for each marked feature.



Measurement Recipe: Spline interpolate (or fit) the smoothed spectrum to 0.1 A grid and search for the λabs, λemi, and λ1peak.

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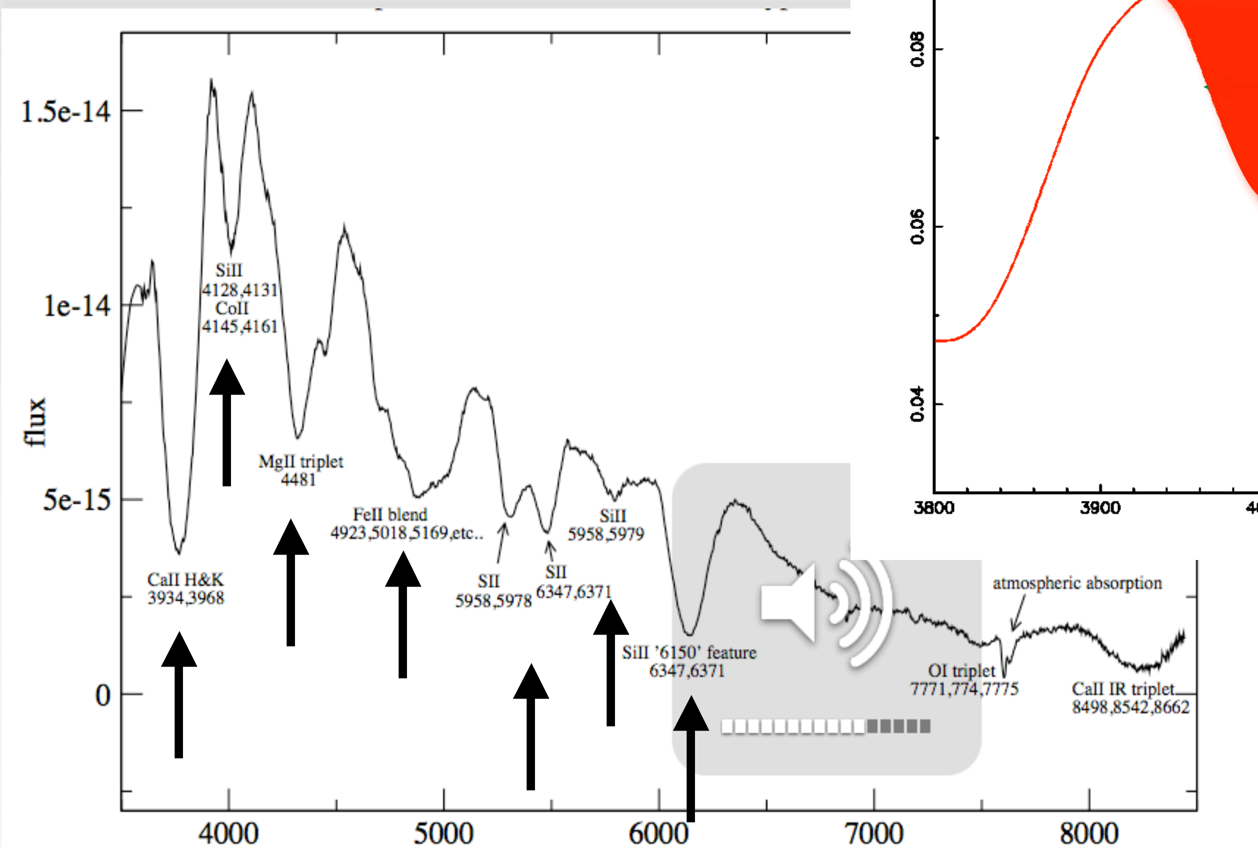

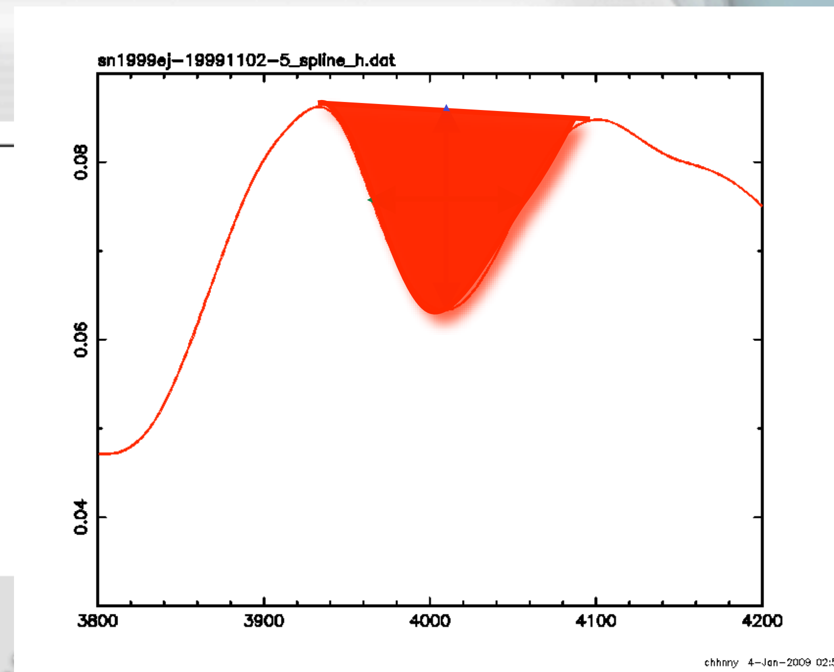

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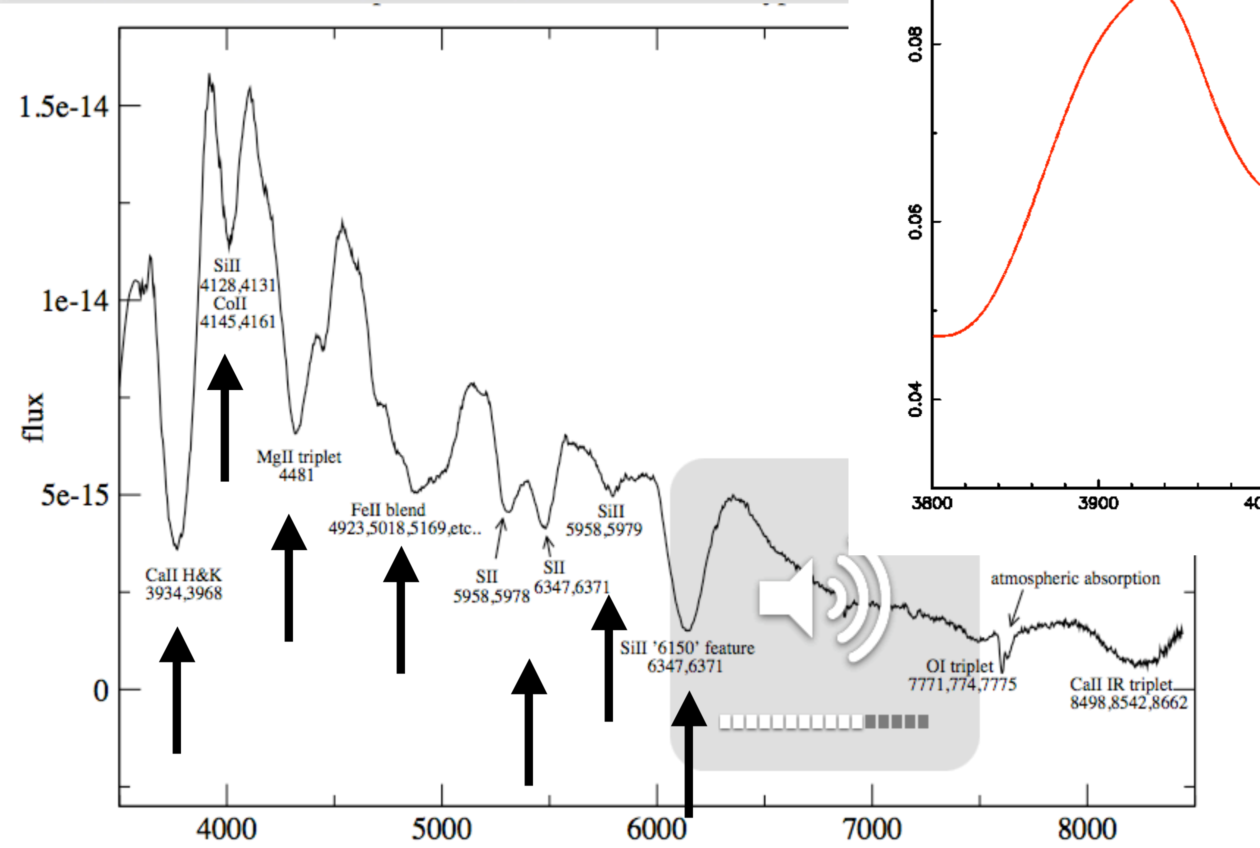

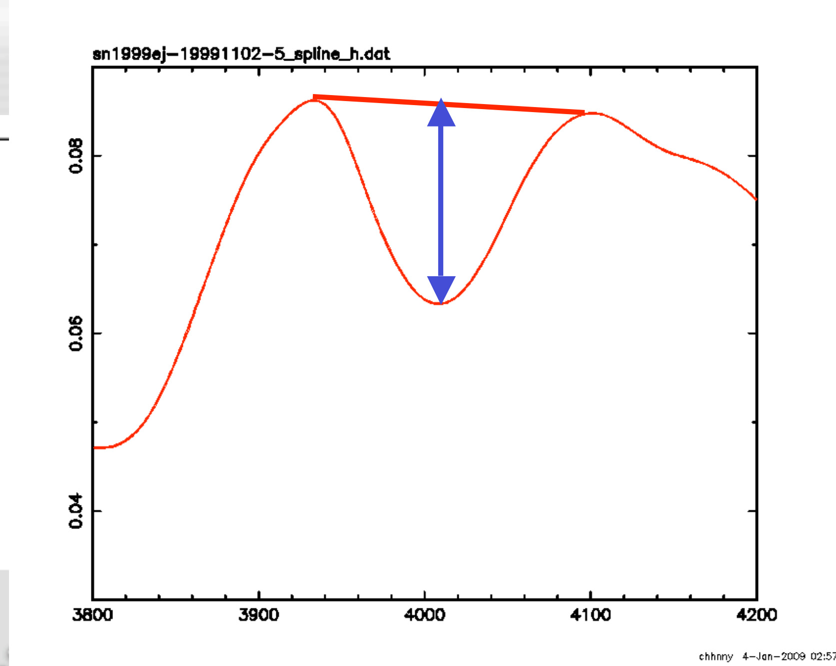

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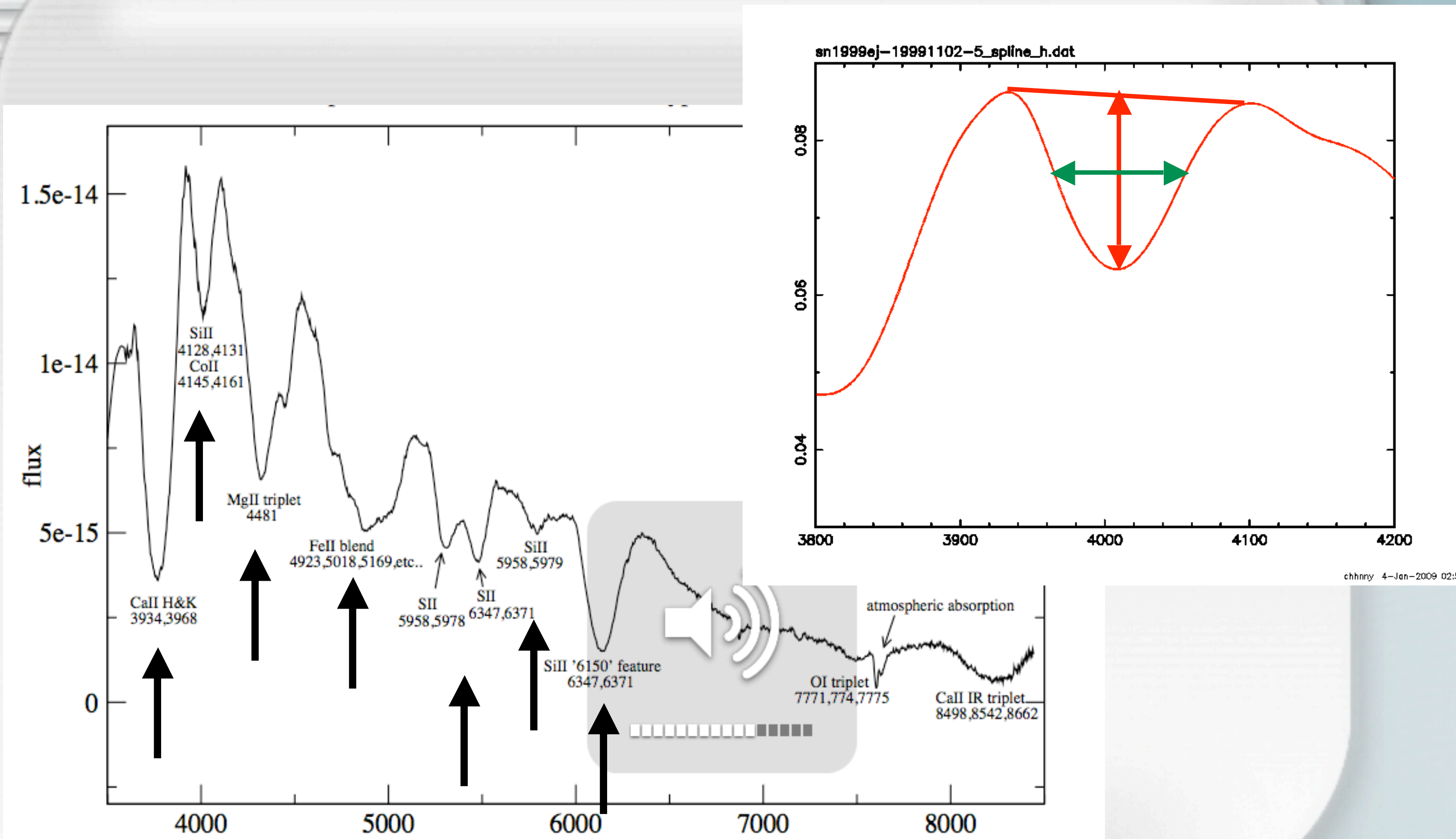


2) Correlate them and their **ratios** with [Δ, MV, SN Colors, Host Colors, Epoch, etc.]. Sort the correlations.

Error Estimation

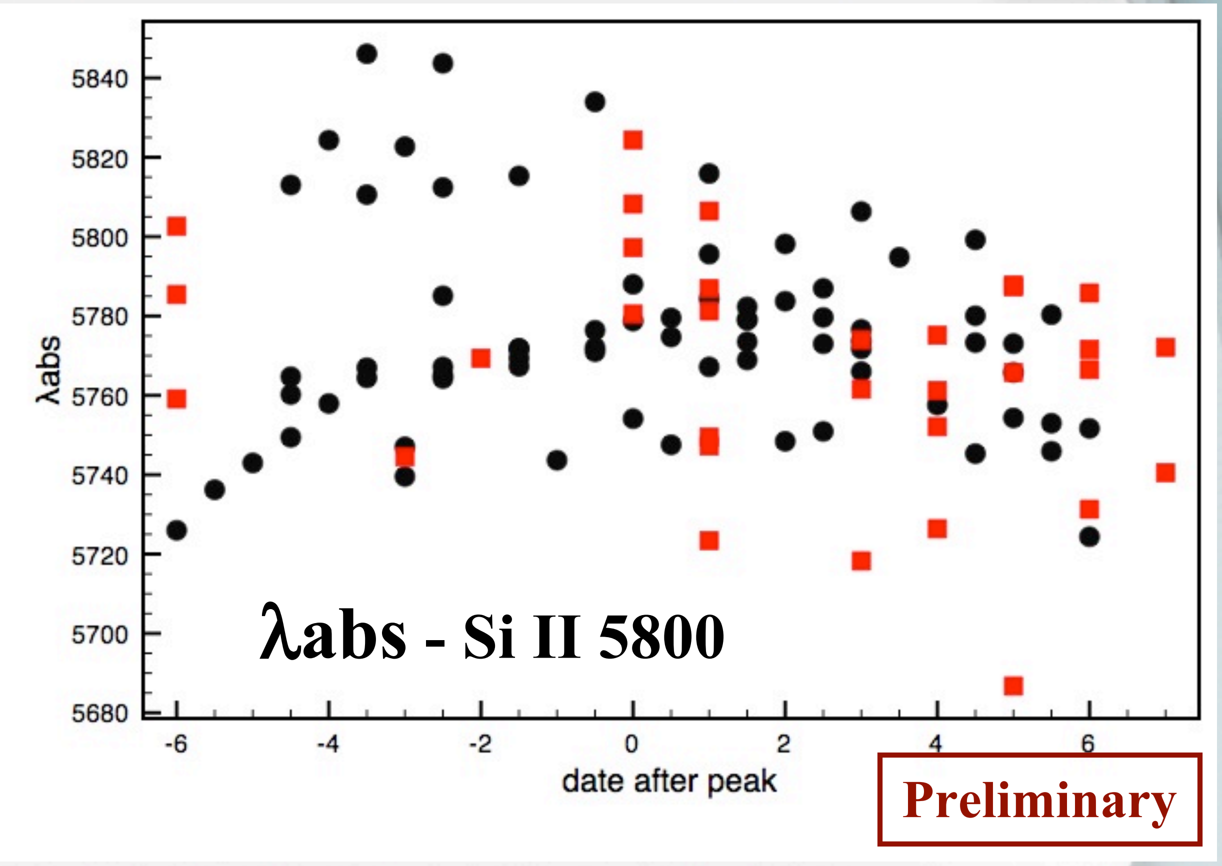
- Determine the errors of λ and flux by varying the the search region of the feature and the fitting functions.
- Spectra variance and systematics from the host subtraction step are included.
- Propagate the measurement errors of λ and flux to the other spectral properties.

Preliminary Results

- **Cfa 1998-2000**
- **SDSS-II SN Survey 2005-2006**

Evolution Effect Check - Line Profile

- The temporal evolution of λ abs, λemi, Vabs, Vemi, and Pseudo-EW are similar for low-z and mid-z Ia's.



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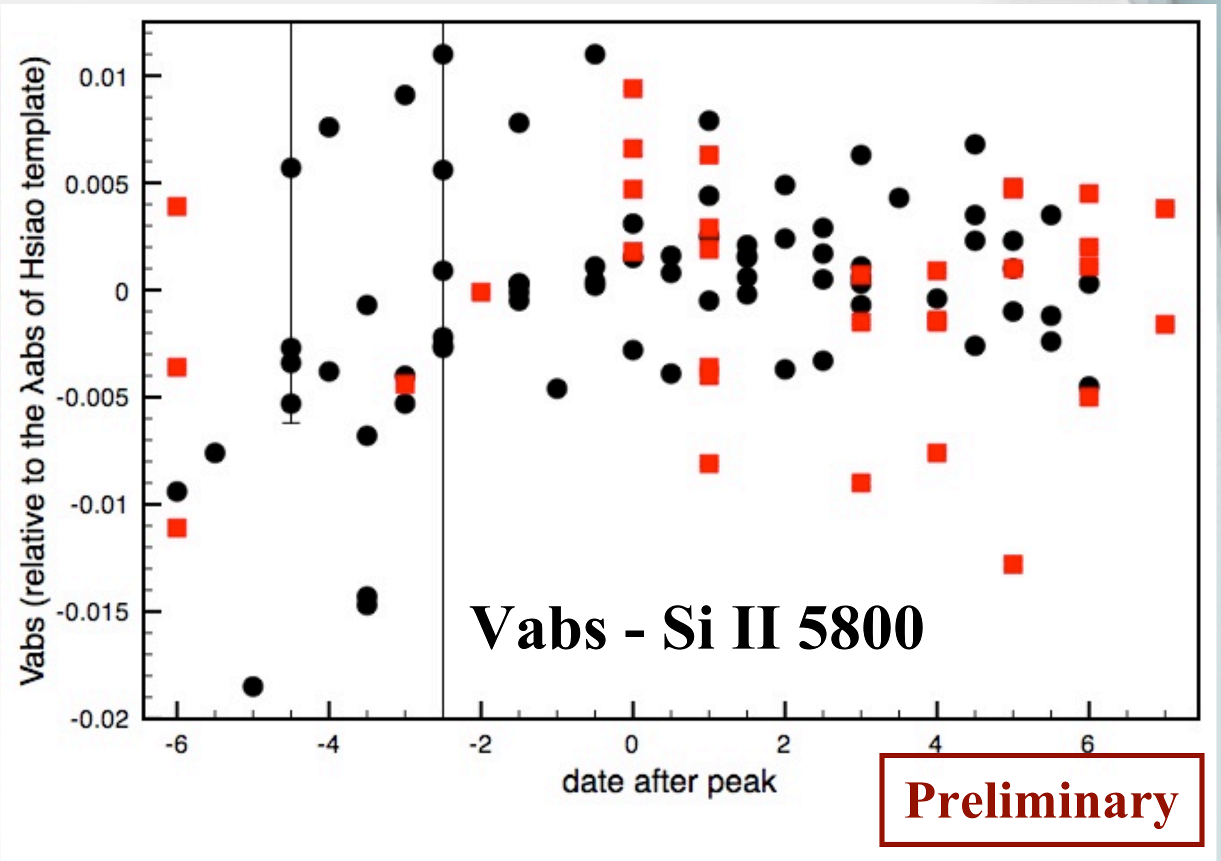
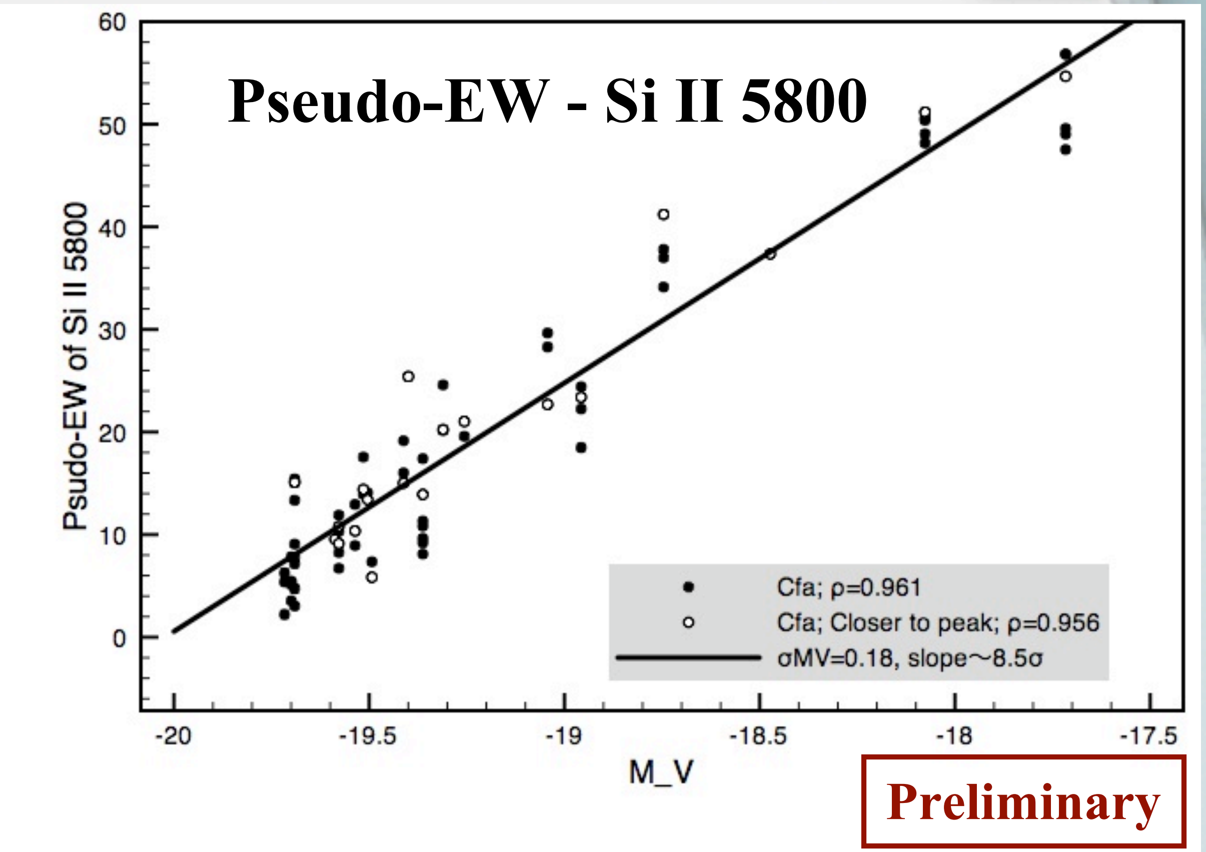


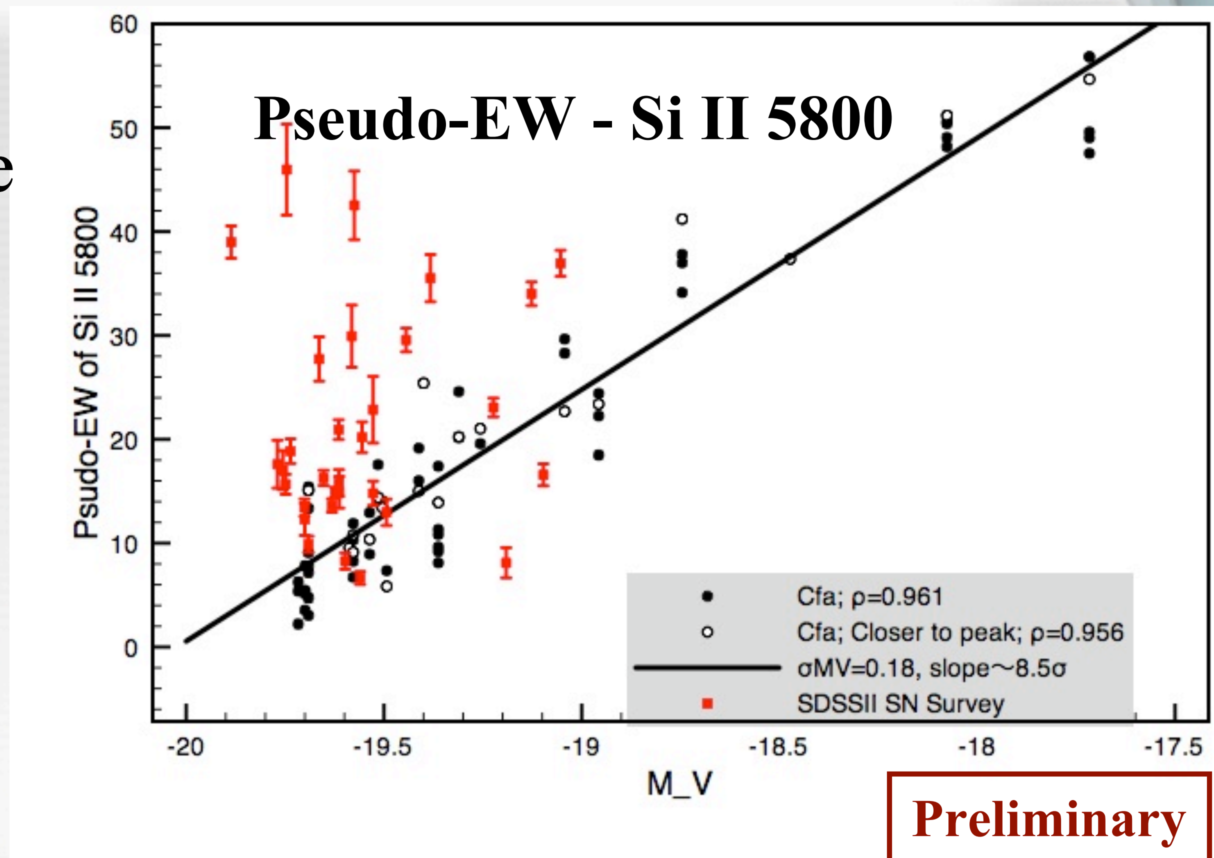
Luminosity Indicator Check

- Cfa sample suggests that Si II 5800 (pseudo-EW or linstr or RSi) is a good luminosity indicator, confirming Hachinger et al. 2008's claim.



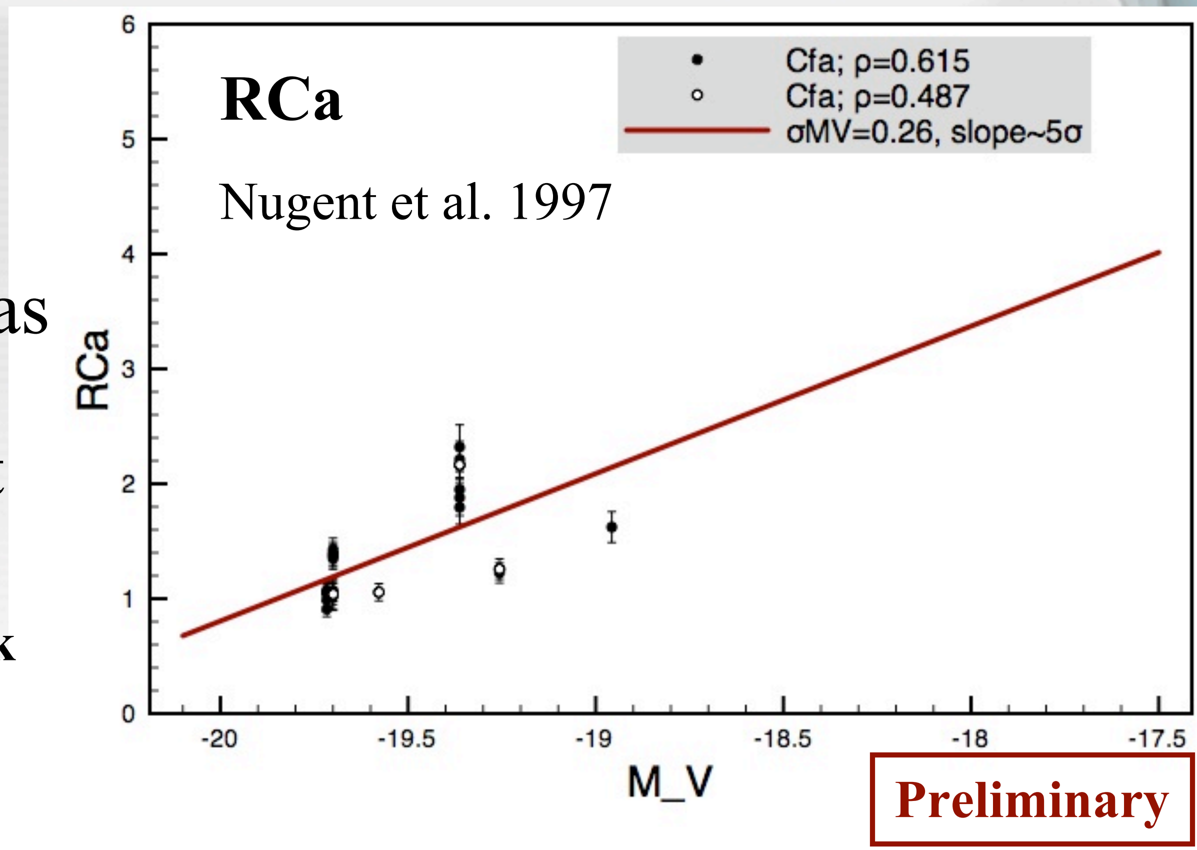
Luminosity Indicator Check

- SDSS-II SN Survey sample suggests a bigger spread.

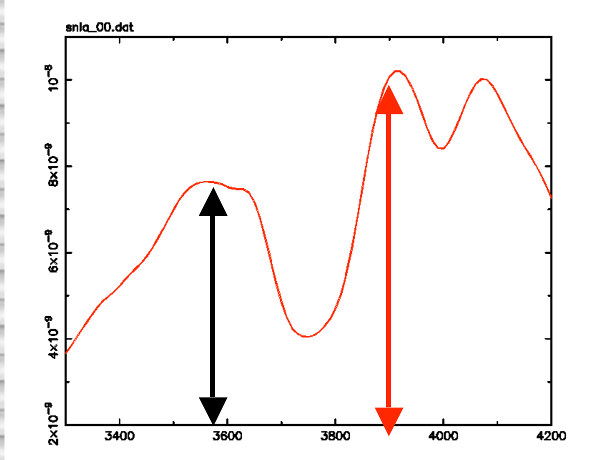


Luminosity Indicator Check

- As a potential luminosity indicator, RCa is not as good as Si II 5800 or RSi (Nugent et al. 1997).



RCa=Red/Black



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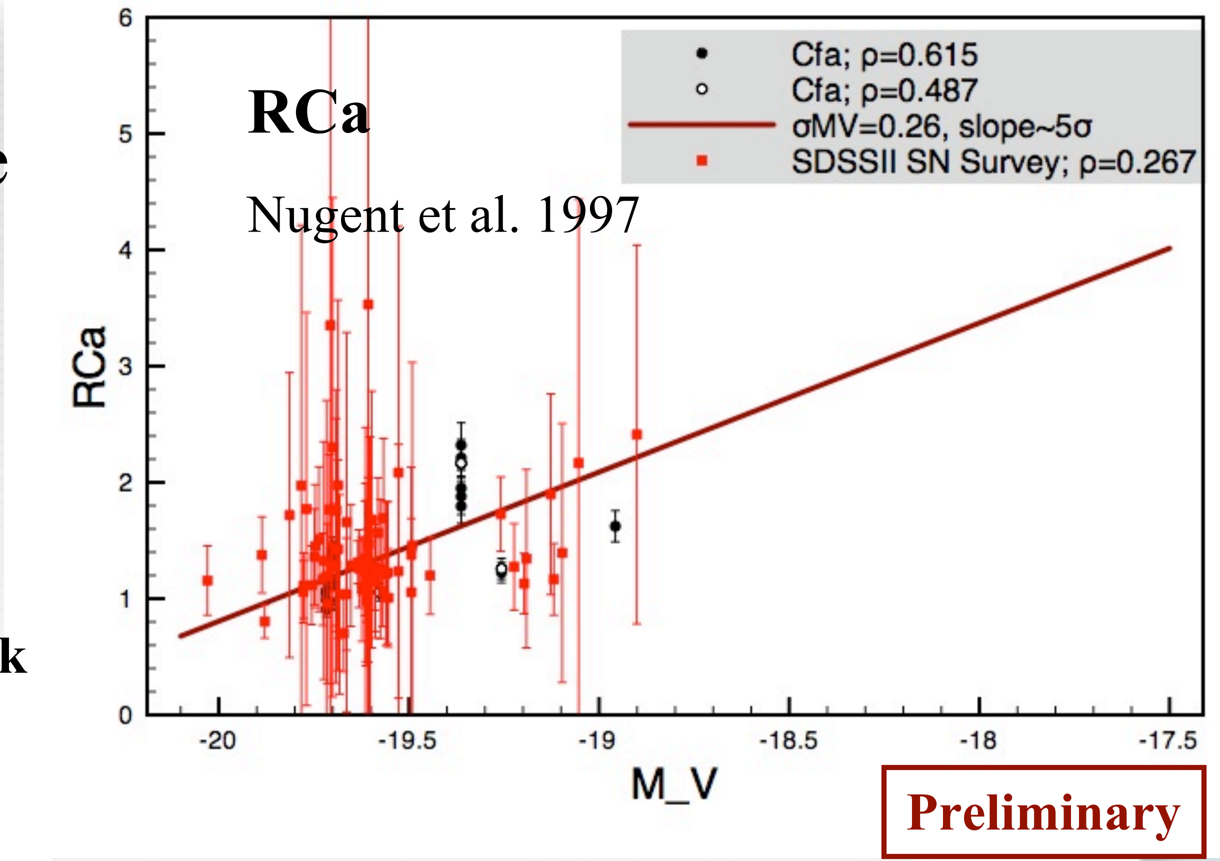

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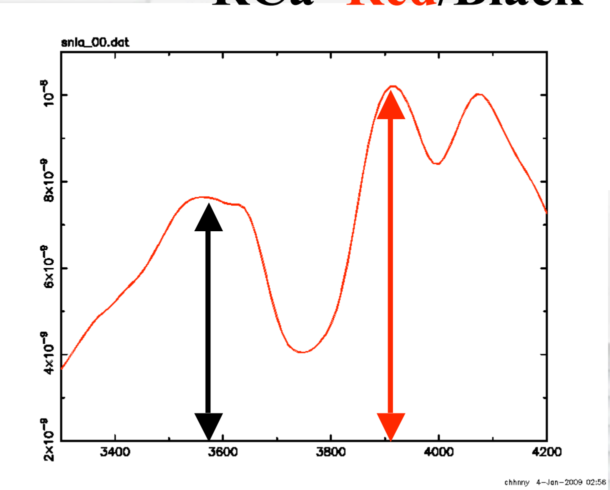
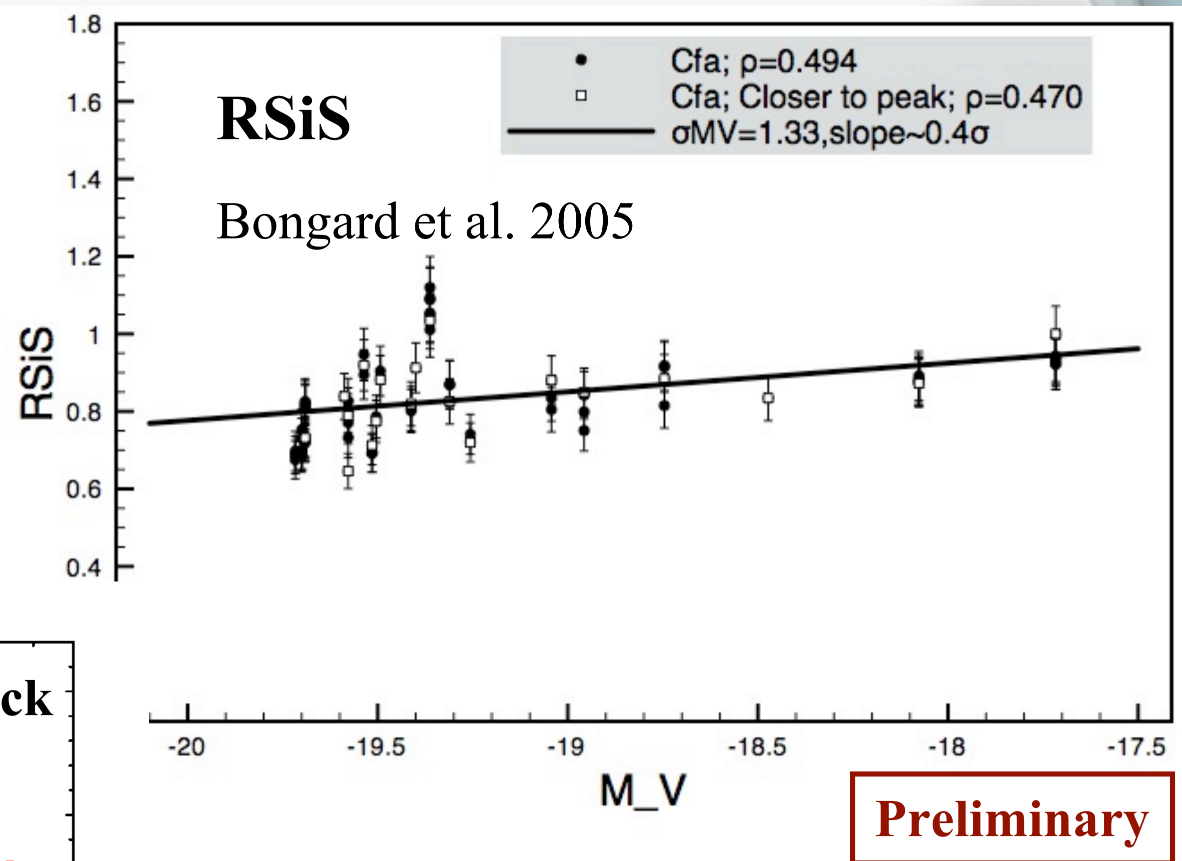
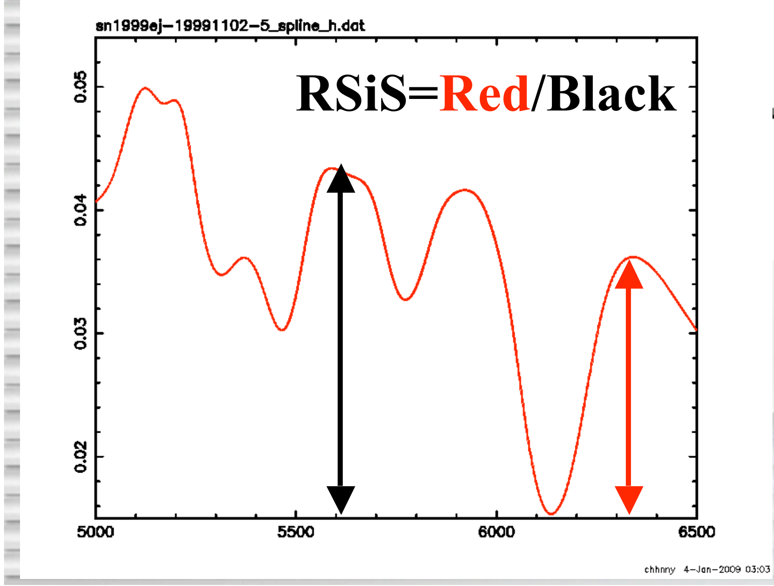


Luminosity Indicator Check

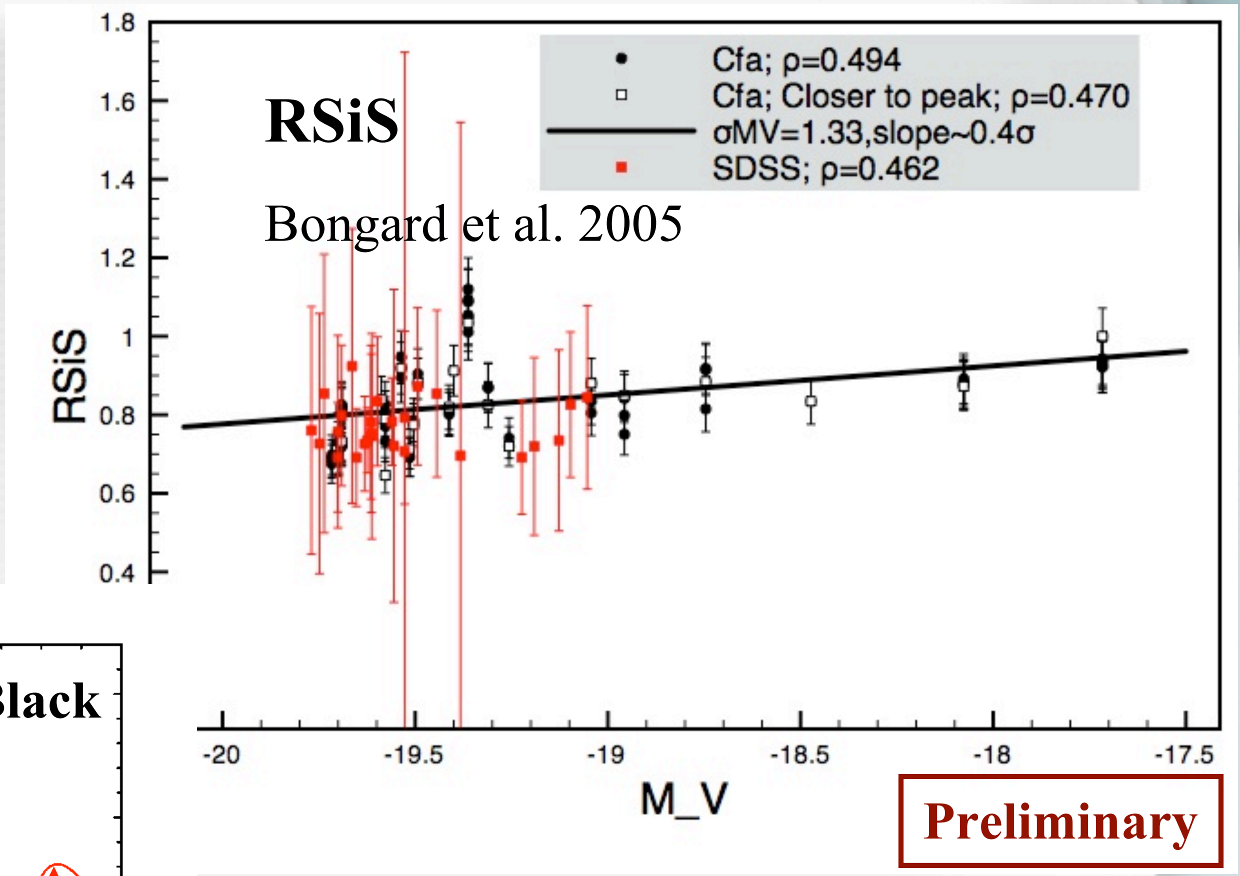
- RSiS seems to be independent of MV, suggested by the Cfa sample

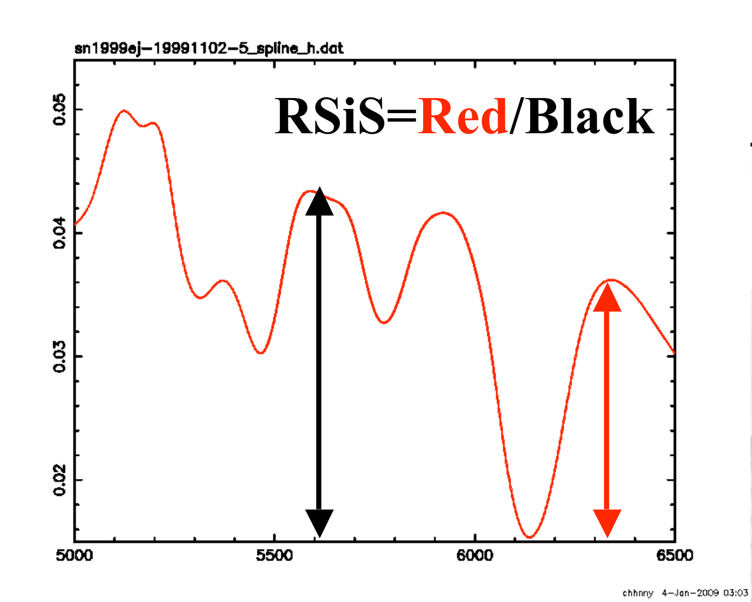




Luminosity Indicator Check

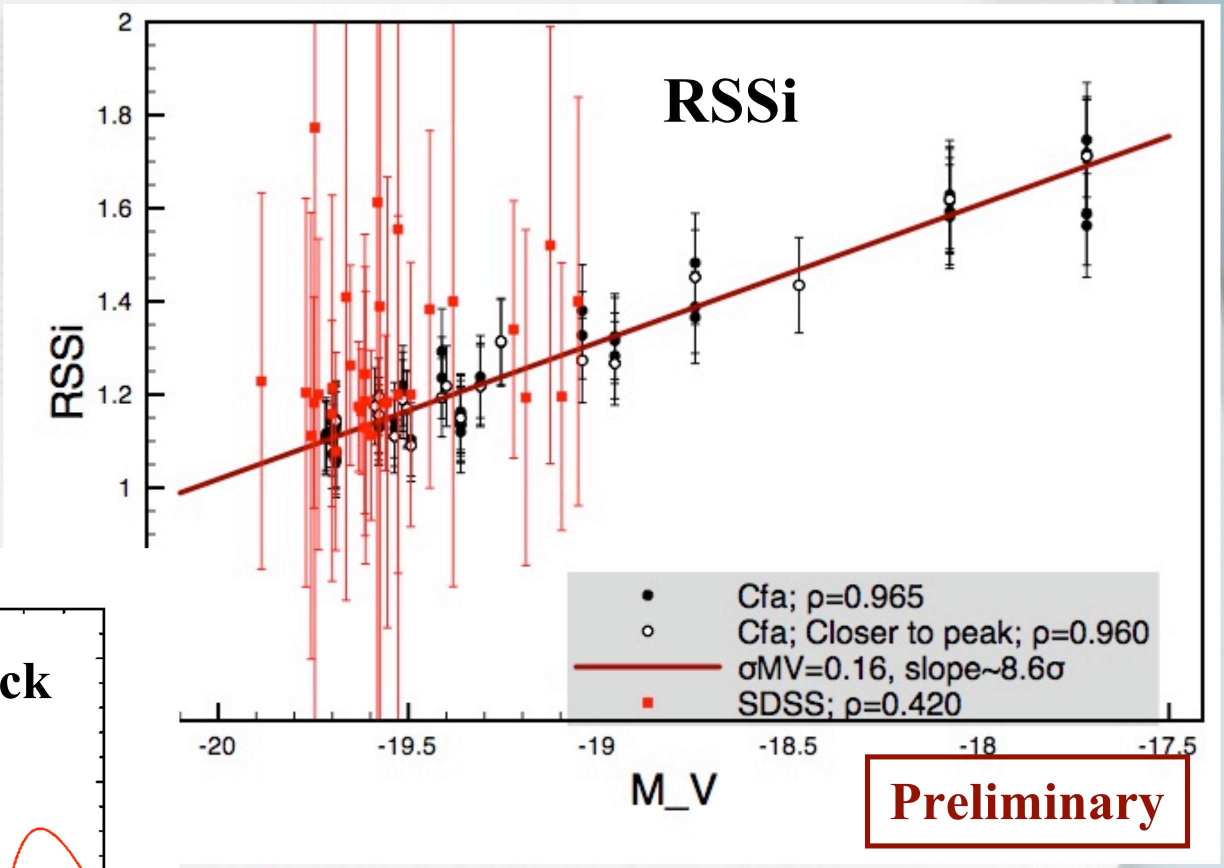
- … and SDSS II SN Survey sample.

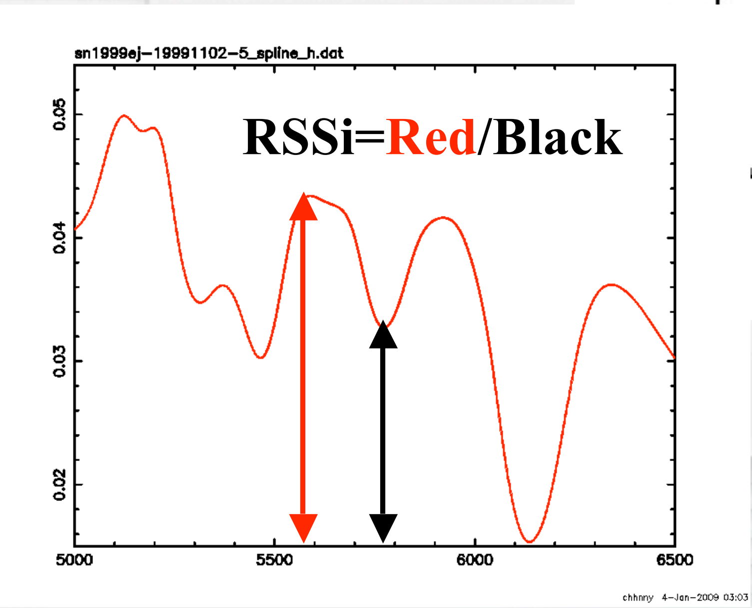




NEW Luminosity Indicator?: RSSi

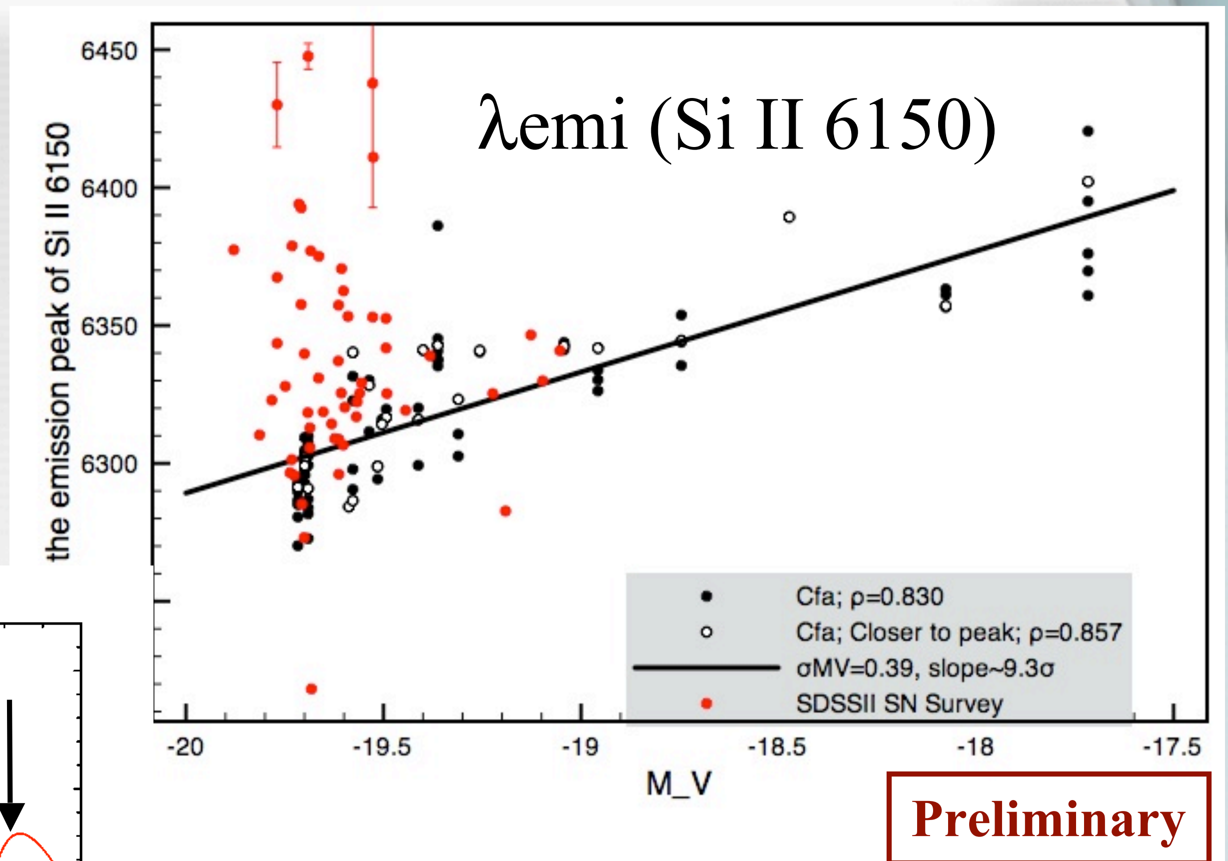
- We have found a few new potential luminosity indicators, e.g. RSSi …

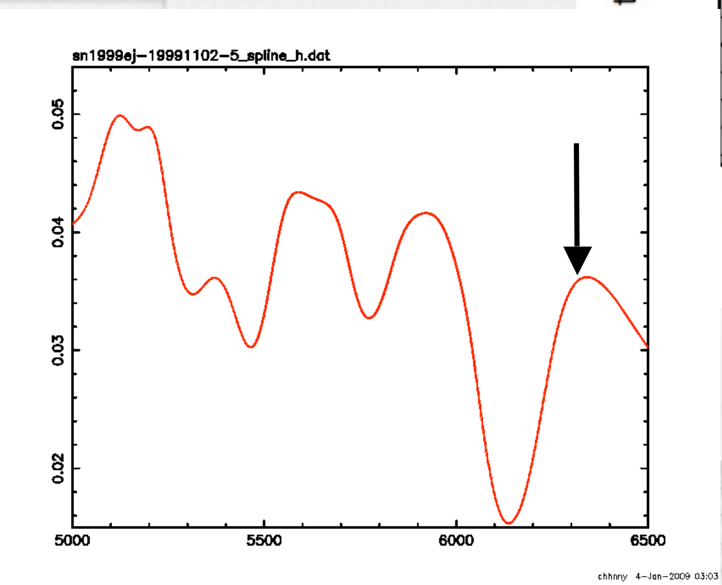




NEW Luminosity Indicator?: λemi (Si II)

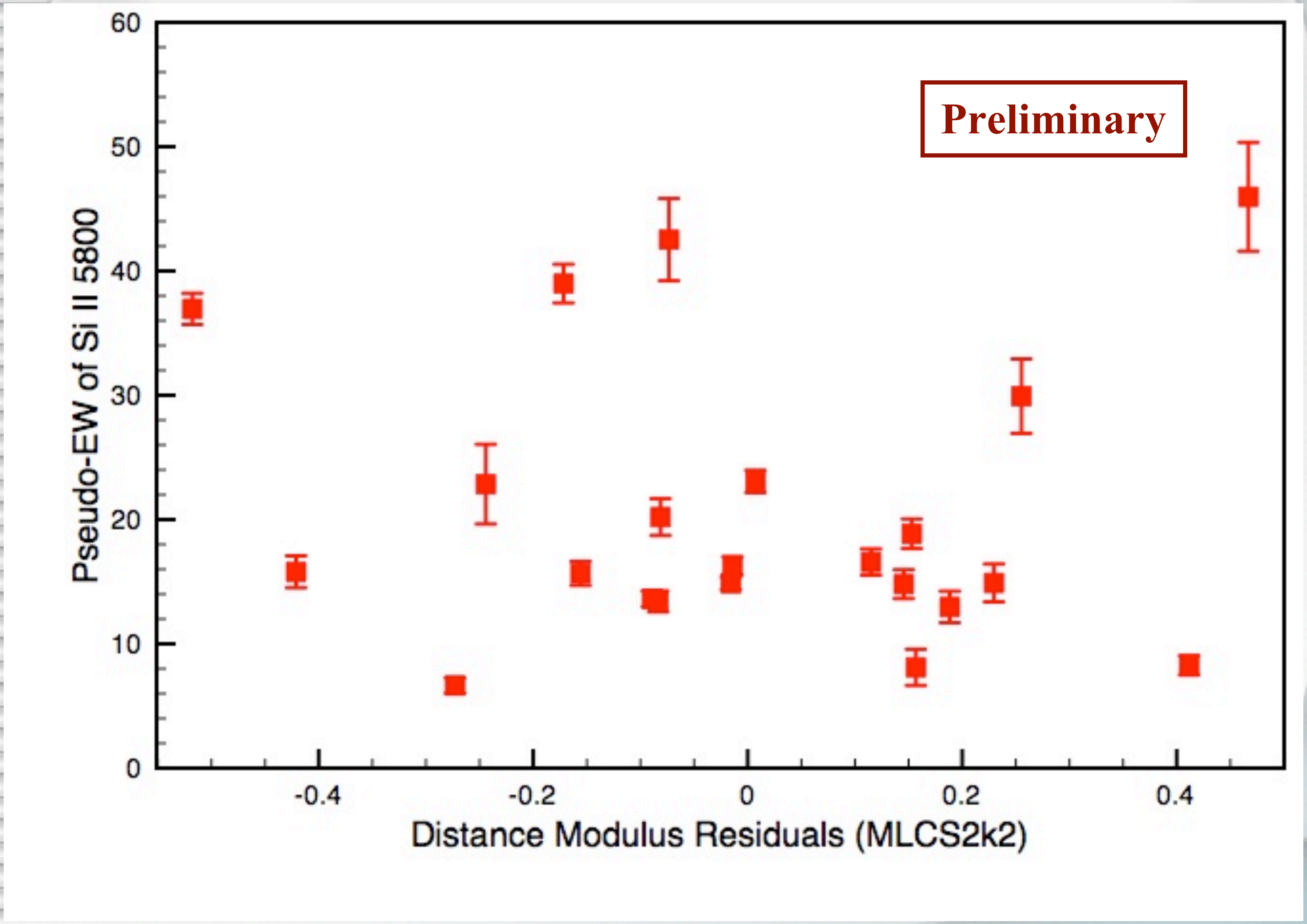
- … and λemi (Si II 6150)





Preliminary

Correlation with Distance Modulus Residual?



Summary

- We have developed an effective host-subtraction tool and a spectral measurement and correlation pipeline.
- We have assembled a set of host-free spectra from SDSS-II SN Survey and measured their spectral properties.
- The mid-z Ia spectra, in many ways, are similar as the low-z ones.
- Well-known luminosity indicators RSi/EW_SiII5800 are supported by our study. We also have found a few new potential luminosity indicators, e.g. RSSi.